DOCUMENT RESUME

ED 173 652 CE 022 321

AUTHOR Ross-Harrington, Melinda; Kincaid, G. David
TITLE Water Treatment Technology - Wells.
INSTITUTION West Virginia Research Coordinating Unit for Vocational Education, Huntington.; West Virginia State Dept. of Education, Charleston. Bureau of Vocational, Technical, and Adult Education.; West Virginia State Dept. of Health, Charleston.
SPONS AGENCY Office of Education (DHEW), Washington, D.C.
PUB DATE Dec 78
GRANT G007603801; H007800069
NOTE 42p.; For related documents see CE 022 313-324 ; Not available in hard copy due to marginal legibility

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Adult Education; Educational Objectives; Evaluation Methods; Individualized Curriculum; Instructional Materials; *Job Skills; Learning Activities; Public Health; Trade and Industrial Education; *Utilities; Water Resources
IDENTIFIERS *Water Treatment; *Wells; West Virginia

ABSTRACT

One of twelve water treatment technology units, this student manual on wells provides instructional materials for five competencies. (The twelve units are designed for a continuing education training course for public water supply operators.) The competencies focus on the following areas: dug, driven, and chilled wells, aquifer types, deep well construction details, yield and drawdown tests, and well screens. for each competency, student objectives, resources (information sheets and appendix materials), learning activities, and evaluation activity are provided. The appendices contain information on ground water supplies and wells. Generally, an evaluation form with answer key is provided for each competency. (JH)

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Water Treatment Technology

WELLS

Developed by
Melinda Ross-Harrington
Field Tested and Revised by
G. David Kincaid
Research Coordinating Unit
for Vocational Education
Marshall University
Huntington, West Virginia

December, 1978

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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U.S.O.E. Original Grant No. G007603801 &
U.S.O.E. Field Test Grant No. H007800069

CE 022 321

WELLS

EVALUATOR'S COPY

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ACKNOWLEDGEMENTS

Project Co-Directors

Col. T. A. Welty
Coordinator of Public Service Occupations Education
Bureau of Vocational, Technical, and Adult Education
West Virginia State Department of Education
Charleston, West Virginia

Donald Kuntz, P.E.
Chief, Drinking Water Program
Environmental Health Services
West Virginia Department of Health
Charleston, West Virginia

David Ball, P.E.
Engineer, Drinking Water Program
Environmental Health Services
West Virginia Department of Health
Charleston, West Virginia

Graphics

Robert Lilly
Vocational Curriculum Laboratory
West Virginia Bureau of Vocational, Technical, and
Adult Education
Cedar Lakes Conference Center
Ripley, West Virginia

Typing/Editing

Joann Turner and Kristine Standifur
Research Coordinating Unit for Vocational Education
Marshall University
Huntington, West Virginia

EVALUATOR'S INSTRUCTIONS

Name _____

Address _____

_____

Phone _____

This is your EVALUATOR'S COPY of the WELLS unit. It contains all of the materials received by the operators who will be working on the unit. It also contains *answer keys* and *directions* for the evaluation of each Competency. For each Competency Sheet, there is a COMPETENCY, a list of RESOURCES, LEARNING ACTIVITIES, and EVALUATION ACTIVITIES.

Your student operators will call you when they are ready to be evaluated. An operator may complete the evaluations in *any* order. S/he may choose to complete one at a time, or several at one time. *It is up to you and each operator to set convenient schedules for the evaluations.* It is important that the operators learn the skills listed in each competency. It is <u>your</u> job to be sure the operators can perform the competencies.

If an operator does <u>not</u> complete an evaluation correctly, s/he may try again later after practicing the skills. It would be helpful for you to tell the operators just how they should improve their knowledge and skills in order to complete the evaluation successfully. Be sure to call if you have any questions.

This package contains:

- - - - - WELLS unit

- - - - - Evaluation Forms for each Competency

You will receive instructions as to where to send the completed evaluation forms. Please be sure that the operator's name and your name are on the forms, as well as the date on which the evaluation was performed.

INSTRUCTIONS FOR THE STUDENT OPERATCR

The WELLS unit contains five competencies. A "competency" is a skill that is necessary for good on-the-job performance. Each competency in this unit is necessary for you to perform on the job according to the West Virginia Department of Health. There is a Competency Sheet to help you understand each competency.

DIRECTIONS FOR COMPLETING THE UNIT:

1. Read each Competency Sheet carefully. Every Competency Sheet contains:

   COMPETENCY
   Objectives
   RESOURCES
   LEARNING ACTIVITIES
   EVALUATION ACTIVITY(IES)

2. After reading the whole Competency Sheet, you should understand what will be expected of you.

3. Do the LEARNING ACTIVITIES that you think will help you the most. This may include reading some of the RESOURCES which have been included with the unit.

4. If you need additional help, ask an operator in your plant for assistance, or call your evaluator; he's there to help you.

5. When you are ready to complete the EVALUATION ACTIVITY for one or more competencies--call your evaluator. The two of you will schedule the best time for your evaluation.

   a. If you complete the evaluation correctly, go on to the next competency.
   b. If you do <u>not</u> complete the evaluation correctly, your evaluator will tell you what your mistakes were. You must go back and practice your skills and read the RESOURCES again. Call your evaluator when you are ready to try again. *You must wait at least one week before being re-evaluated on a competency.*

SEE NEXT PAGE

6. When you complete all your evaluations correctly you will receive a Certificate of Accomplishment and 1.0 Continuing Education Units of Credit.

7. If you want to go on to another unit, contact your evaluator for the materials. The procedure will be similar for all units.

AN EXPLANATION OF CONTINUING EDUCATION UNITS

For student operators in the OPERATOR-IN-TRAINING category who will be taking the certification examination for Class I, this course is an opportunity to increase your knowledge and competence in the treatment of water for human consumption. Successful completion of the manuals will also, it is hoped, make passing the certification exam much easier. The Continuing Education Units which you will get by taking this course will not decrease the minimum one year operating experience requirement for a Class I certificate.

For student operators who now hold a Class I certificate, the completion of all twelve manuals in the course will reduce the currently required three years of total operating experience for Class II certification by approximately four months. Thus, if you complete the course, you will need only two years and eight months of total operating experience before you take the Class II exam.

Here is a listing of the Continuing Education Unit (CEU) value of each of the manuals.

Manual	CEU Value
General Plant Operation	1.4
Taste, Odor, and Color	0.6
Chemistry/Bacteriology	2.5
Chlorination	2.5
Fluoridation	0.6
Filtration	1.2
Hydraulics	0.6
Distribution Systems	1.2
Pumps	0.6
Wells	1.0
Cross Connections	0.4
Springs	0.4
Total	13.0

For comparison with other types of training previously available, the CEU conversions below are given.

Public Water Supply Operator's Short Course (given by State Department of Health Personnel)	4 CEUs
One Semester Hour of College Credit	1.5 CEUs
One Year of College Credits (30 semester hours)	45 CEUs

COMPETENCY: Describe the difference between dug, drilled, and driven wells.

Objective: Describe the construction and operation of dug, drilled, and driven wells.

Objective: Describe the advantages and disadvantages of dug, drilled, and driven wells.

RESOURCES:

(a) "Dug Wells" Resource Sheet I.

(b) "Drilled Wells" Resource Sheet II.

(c) "Driven Wells" Resource Sheet III.

LEARNING ACTIVITIES:

(a) Read the Resources listed above to find information about dug, drilled. and driven wells. Note how each type of well is constructed and its approximate size. Identify the advantages and disadvantages for each type of well.

(b) If your plant uses a well (or wells) as its source of water, closely inspect the well. Identify what type of well it is. Using plant blueprints for the well, note how it is constructed. Describe the aquifer from which the well derives water.

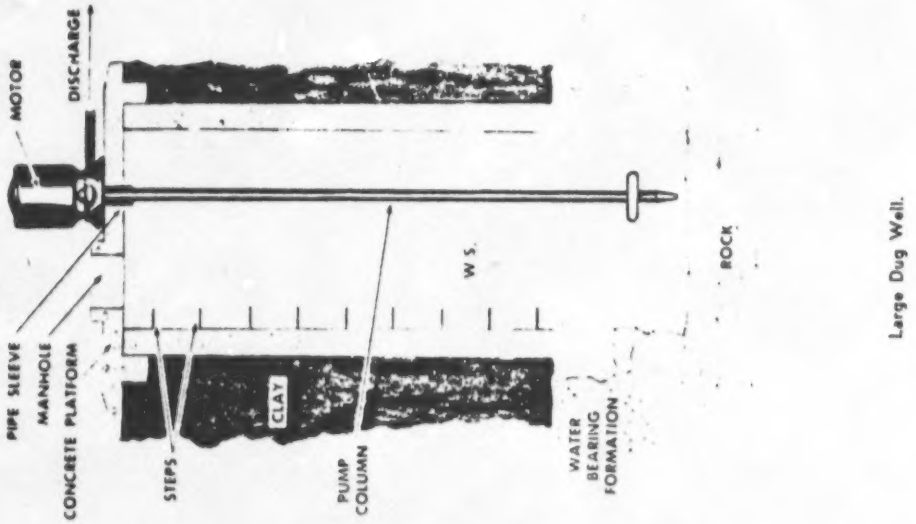
(c) Arrange to visit the sites of dug, drilled, and driven wells. Notice the differences in construction.

EVALUATION ACTIVITY: Complete Evaluation Form #53. It contains questions about the construction and operation of dug, drilled, and driven wells. You many not use references.

"DUG WELLS"*

Dug wells are shallow wells that are excavated with pick and shovel or bucket-type excavating machinery. They are usually between 3 and 6 feet in diameter and not more than 50 feet deep. Concrete, brick, or corrugated metal pipe sections are used for the casing. Unless poured concrete is used to line dug wells, it is difficult to make the lining watertight. As a result, dug wells are not a preferred source of water supply, and until a dug well is proved safe by sanitary inspection and bacteriological analysis it should be regarded with suspicion.

Dug wells are difficult to maintain for structural and sanitary reasons. The wells are usually of large diameter and frequently have masonry or concrete ring casings. These are subject to cracking and joint failure. Such openings in the casing allow contaminated surface water to enter into the shallow wells. Inspect casings periodically and make repairs as soon as defects are found. Since it is difficult to protect dug wells from surface water intrusion, it is necessary to exercise particular care to exclude all sanitary hazards from the area. Dug wells are subject to rapid silting and sanding. Check monthly and clean before more than 1 foot accumulates. When this is done, take care not to excavate too much or the well may cave in. The yield of a dug well may be increased by constructing drilled or driven wells or horizontal sandpoints in the well bottom. These operations require competent well men. Check drainage to well after each rain to see that surface water is properly diverted.

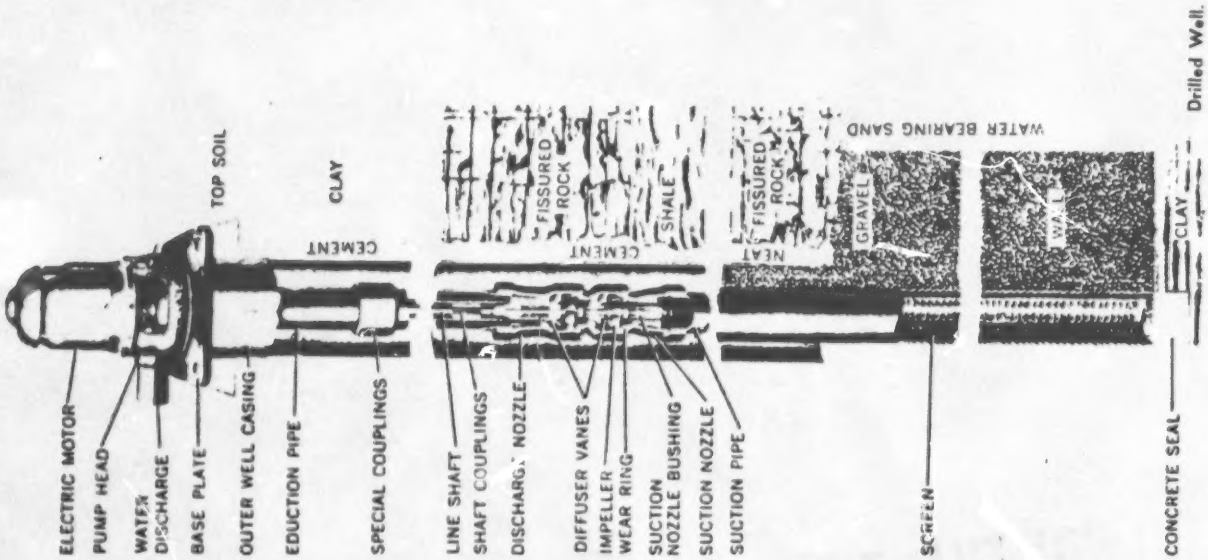


*Source: Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Air Force Manual No. 85-13, June 15, 1968, p. 30.

"DRILLED WELLS"*

Where the underlying ground is hard or rocky or the aquifer is deep, wells are generally drilled. Drilled wells may be up to four feet in diameter and thousands of feet deep. Drilling requires the erection of a derrick or the use of a crane to hold the drilling tools and to guide and power them into the earth. The drilling bit is forced through earth and rock by being repeatedly lifted and dropped on the end of a cable or by being rotated on the end of a shaft. Power is supplied by gasoline or diesel engines through associated pulleys, gears, shafts, and other machinery. As the drill descends into the ground, a casing of steel pipe is forced down with it by hydraulic jacks or other means. Lengths of casing and drill shaft are added at the ground surface as needed. Since drilling can penetrate any type of soil or rock to any desired depth, most wells are made in this manner. This is particularly true of wells used for Air Force water supplies because it is usually necessary to go to greater depths than can be reached by boring, digging, or driving in order to tap an aquifer of sufficient capacity. Another advantage of drilled wells is that deep water usually obtained has filtered through more earth for a longer period of time than water in shallow aquifers and therefore contains less bacteria. Also, the use of steel pipe for casing allows the well to be made watertight all the way down to the aquifer so no surface water can contaminate it.

Drilled wells have tight metallic casings and require little structural maintenance. The most vulnerable part is the screen, which may clog with silt, sand, or scale. Since drilled wells are usually deep, it is a major job to inspect or remove the screen, and other remedial measures should be tried first.



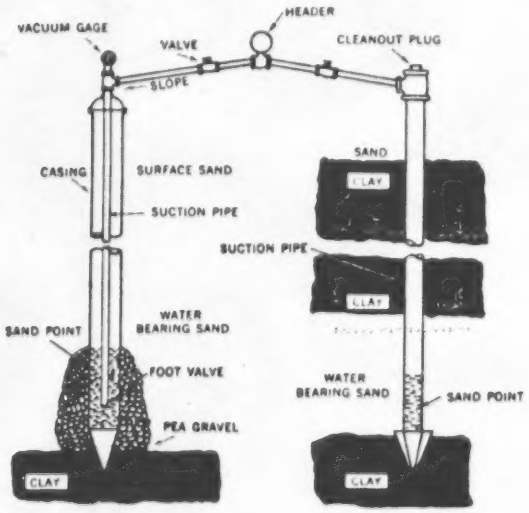
*Source: Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Air Force Manual, No. 85-13, June 15, 1968, pp. 31-32.

"DRIVEN WELLS"*

Shallow wells of small diameter (usually 1½ inches to 3 inches) may be driven into soft ground by mauls or by dropping weights. A steel pipe fitted with a "point" of slightly greater diameter than the pipe is pounded into the ground in this manner. Just above this driving point on the pipe are perforations or slits which, when the pipe is driven into place in the aquifer, allow the water to enter. A screen is wrapped around the perforated section to keep sand and earth from passing into the pipe. Sometimes a number of well points or sand-point wells, as driven wells are also called, are driven near each other and connected to the suction of a pump through a common header to produce the amount of water that the aquifer will yield.

When a well point is driven, the screen of metal gauze or wrapping on the point may be damaged or sealed off. Well points may clog due to silting, sanding, or corrosion over a period of time. When water production falls off and well point clogging or damage is suspected, backwash by pumping water back through the point until pressure indicates the point is open.

CAUTION: Do not use pressures over 150 pounds per square inch because screen will be damaged. If backwashing does not open well point screen, pull the point and clean it with a brush and water, or, if necessary, replace it.



Well Point Battery.

*Source: Maintenance and Operation of Water Plants and Systems, Department of the Air Force, Air Force Manual No. 85-13, June 15, 1968, pp. 30-31.

Operator _____

Evaluator _____

Date _____

Directions: Write the word "True" or "False" next to each item in the space provided. If you answer "False" write the correct answer on the lines under the question.

1. *True* Dug wells are shallow--usually less than 50 feet deep.

2. *False* Driven wells are constructed when the ground is very hard or rocky.

Driven wells are constructed in soft ground by mauls or by dropping weights.

3. *False* Dug wells need very little maintenance.

Dug wells are subject to rapid silting and sanding; drainage to well must be checked after every rain; ring casings are subject to cracking and joint failure.

4. *True* The screen of a drilled well may clog with silt, sand, or scale.

5. *True* If the water production of a driven well drops, the well points may be clogged.

6. *False* Dug wells are the most appropriate type of well for water systems serving a large population.

Drilled wells are preferred because they can penetrate any type of soil or rock to any desired depth.

7. *True* Casing for dug wells is usually concrete, brick, or corrugated metal.

8. *True* Casing for drilled wells is usually steel pipe.

COMPETENCY: Describe the various types of aquifers from which wells may derive water.

Objective: Describe the function of an aquifer.

Objective: Describe the differences between types of aquifers.

RESOURCES: (a) Manual of Instruction for Water Treatment Plant Operators, New York State Dept. of Health, Health Education Service, P.O. Box 7283, Albany, N. Y. 12224, pp. 10-13. *-Blue Appendix-*

LEARNING ACTIVITIES: (a) Read the Resource listed above to find information about aquifers.

(b) Describe confined aquifers and unconfined aquifers. What are the basic differences in the two types of aquifers? How does the type of aquifer affect the type of well to be constructed?

EVALUATION ACTIVITY: Complete Evaluation Form #54. It contains questions about the various types of aquifers from which wells may derive water. You may not use references.

(Wells #54)
Evaluation Form
EVALUATOR'S COPY

Operator _____

Evaluator _____

Date _____

Directions: Write the word "True" or "False" in the space provided next to each item. If you answer "False" write the correct answer on the lines under the item.

1. *True* An artesian well contains water under pressure.

2. *False* Artesian wells are usually quite shallow.

Artesian wells tend to be quite deep.

3. *True* A "free surface well" draws water from an unconfined aquifer.

4. *False* An unconfined aquifer contains water under pressure.

An unconfined aquifer contains water with a free surface at atmospheric pressure.

5. *True* Free surface wells tend to be shallow.

COMPETENCY: Sketch a deep well labeling all the parts including the following:

gravel wall	vent
screen	casinghead appurtenances
casing	blowoff
cement seal	drawdown gauge
pump bowls	drop line and/or sensors

Objective: Identify all important components of a well.

Objective: Describe the purpose of each of the well components listed in the Competency.

RESOURCES:

(a) Water Works Operators Manual, Alabama Department of Public Health, Bureau of Environmental Health, Third Edition, 1972, Chapter IX. *-Yellow Appendix-*

(b) Manual of Instruction for Water Treatment Plant Operators, New York State Dept. of Health, Health Education Service, P.O. Box 7283, Albany, N. Y. 12224, pp. 10-13. *-Blue Appendix-*

LEARNING ACTIVITIES:

(a) Read the Resources listed above to find information about well construction.

(b) If possible, visit a site where a well is being constructed.

EVALUATION ACTIVITY: Sketch a deep well labeling all important parts including the following:

gravel wall	vent
screen	casinghead appurtenances
casing	blowoff
cement seal	drawdown gauge
pump bowls	drop line and/or sensors

You may not use references, but you may refer to the list above.

COMPETENCY: Describe the purpose of a yield and drawdown test for a new well.

Objective: Describe what "yield" means in relation to a well.

Objective: Describe what "drawdown" means in relation to a well.

Objective: Describe the procedures for a yield and drawdown test for a new well.

RESOURCES: (a) Water Works Operators Manual, Alabama Department of Public Health, Bureau of Environmental Health, Third Edition, 1972, Chapter IX. *-Yellow Appendix-*

LEARNING ACTIVITIES: (a) Read the Resource listed above to find information about a yield and drawdown test.

(b) Observe the testing of a well. Note that a pump much larger than the permanent pump is used. It is powered by a variable drive engine to make tests of varying capacities. The test should be long enough so that stabilization of the water level is established and the safe yield is determined.

Keep a record of all the steps involved in testing a well. Note how each step is performed and how long it takes.

EVALUATION ACTIVITY: You will be expected to describe the purpose of a yield and drawdown test for a new well.

COMPETENCY: Describe the purpose of the well screen and tell what you do to maintain it.

Objective: Describe the construction of a well screen.

Objective: Explain how a well screen protects the water supply.

RESOURCES:

(a) Water Works Operators Manual, Alabama Department of Public Health, Bureau of Environmental Health, Third Edition, 1972, Chapter IX. *-Yellow Appendix-*

(b) "Well Screens" Resource Sheet.

LEARNING ACTIVITIES:

(a) Read the Resources listed above to find information about well screens.

(b) If possible, visit a site where a well is being constructed, or speak with an operator who was involved when a well was being constructed. Determine the location of the well screen and how a screen is selected for a particular well.

EVALUATION ACTIVITY: Complete Evaluation Form #57. You may not use references.

"WELL SCREENS"*

Where water is obtained from water-bearing sands, some type of screen must be provided. The selection and construction of the screen is very important. The life of the well depends to a large degree on the proper screen. *The screen is a device to hold back sand or any other foreign matter and let water through to the pump.* The screen is placed in the well where it is not available for inspection or repair. The life and performance of the well is dependent upon it.

The two most important items for consideration in selecting the screen are the size of the sand encountered and the chemical characteristics of the water. The screen openings must be small enough to hold back the larger sand grains and gravel and at the same time be as large as possible so that resistance to the flow of water is reduced. The screen openings are determined after the sand size is determined. If the screen is improperly sized or ruptures and permits sand to pass, the pump, valves, and meters in the distribution system will be damaged and last only a short time. Meters will become plugged and there may be complaints of sand in the water.

Many waters are corrosive. Screens installed in such wells must be made of material that will resist corrosion. Ordinary steel or other non-corrosion resistant material will last only a relatively short time. Certain stainless steel alloys are the best reasonably priced materials for use. Monel metal, a high nickel-copper alloy is probably the best material used to make screens to be installed in acid waters.

An item which might also be classed as part of the screen is the "gravel wall" built in many wells. Gravel walls serve as filters.

*Source: Water Works Operators Manual, Alabama Department of Public Health, Bureau of Environmental Health, Third Edition, 1972, Chapter IX, pp. 7-8.

(Wells #57)
Evaluation Form
EVALUATOR'S COPY

Operator _____

Evaluator _____

Date _____

Directions: Write the word "True" or "False" in the space provided next to each item. If you answer "False" write the correct answer on the lines below the question.

1. *False* Well screens are replaced once a month.

The screen is placed where it is not available for inspection or repair.

2. *True* The purpose of the well screen is to hold back sand and other matter from the pump.

3. *False* Ordinary steel is good material for a well screen to be made of.

Ordinary steel would probably not last long. Corrosion resistant materials should be used.

4. *True* A gravel wall helps to "screen" the water.

5. *True* The size of sand in the water will affect the type of well screen selected.

GROUND WATER SUPPLIES*

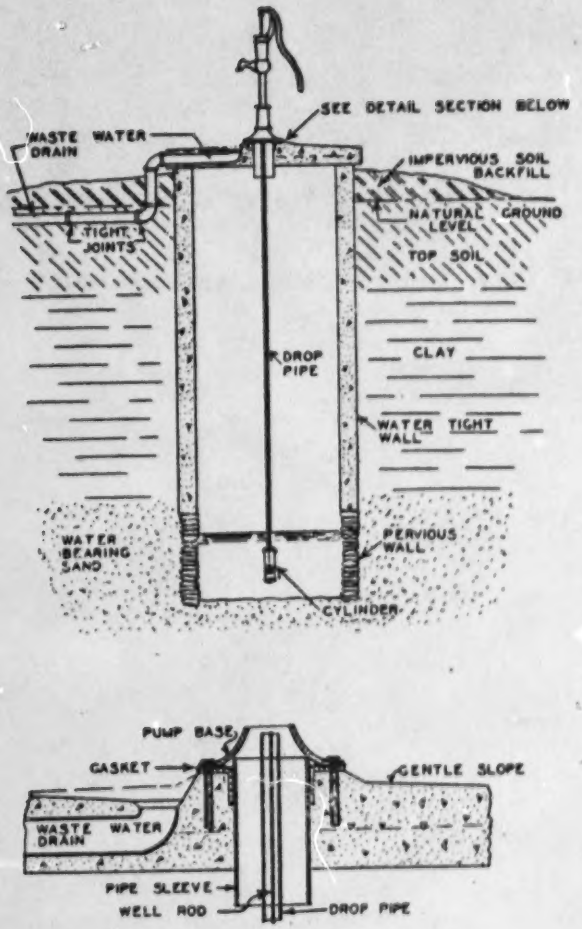
In general, ground water supplies are used only by smaller communities because of the limited quantity that can be obtained from an aquifer. One possible objection to an underground supply is that the water may be excessively hard. This is due to the percolation of the water through mineral deposits from which constituents which cause hardness are leached. On the other hand, an underground supply usually has the advantage of requiring a minimum degree of treatment because of natural purification as the water passes through the various underground soil formations. These conditions are general. Some mineral deposits do not contribute to the hardness and some underground formations do not effectively remove objectionable material.

Types of Ground Water Sources. Ground water sources are most often wells. Infiltration galleries and springs are sometimes used. Wells may be classified as to the type of aquifer from which they derive the water or as to the type of construction. If it draws water from an unconfined aquifer, it is called a "free surface well", "gravity well" or "water table well". An unconfined aquifer is one which contains water with a free surface at atmospheric pressure. If the well draws water from an aquifer which is confined both above and below, and contains water under pressure, it is called an "artesian well" and the aquifer is known as an artesian aquifer. Free surface wells tend to be shallow and the artesian wells deep. Shallow wells are commonly dug or driven wells and deep wells are usually drilled.

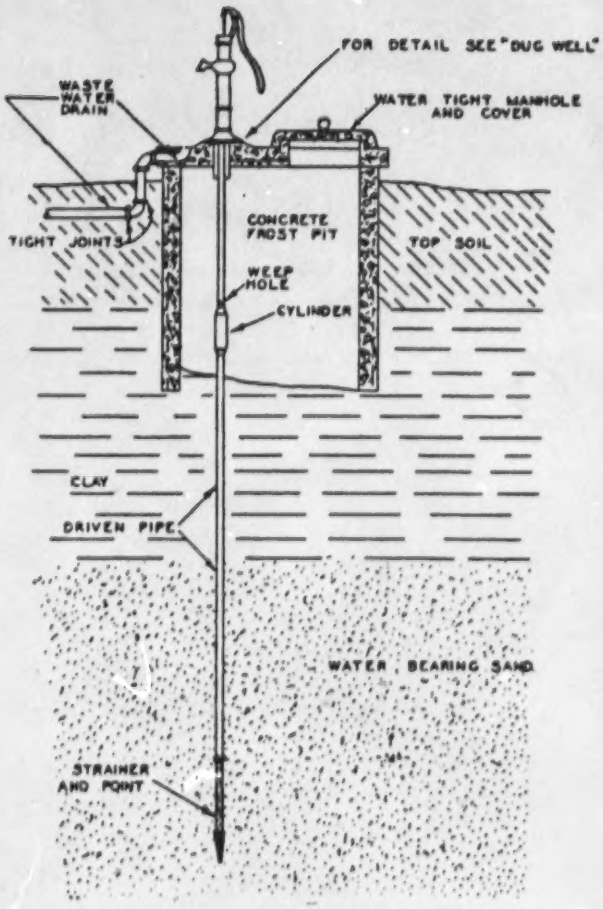
A dug well consists of a vertical hole, usually four to six feet in diameter, which is excavated through top soil until the water bearing stratum is encountered. Such wells may be lined with concrete, brick, rough stone, or vitrified tile. That portion of the lining extending from about one foot above the ground surface to at least ten feet below the surface should be watertight to exclude any surface drainage. Concrete is the best material for the upper part of the well; brick, rough stone or vitrified tile is usually used for the pervious section which extends down into the water bearing stratum.

Driven wells may be used when ground water is within about twenty-five feet of the ground surface and when there are no boulders or intervening rock formations. Such wells are easily constructed and can be protected against superficial pollution, although they are more subject to pollution than deep wells penetrating impervious material. The simplest type of driven well consists of a perforated brass strainer which is cone shaped at the end and which is attached to the bottom of an iron pipe. The pipe is driven through the upper soil layers and into the water-bearing material.

*Source: Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Health Education Service, P.O. Box 7283, Albany, N. Y. 12224, pp. 10-13.



TYPICAL SHALLOW DUG WELL

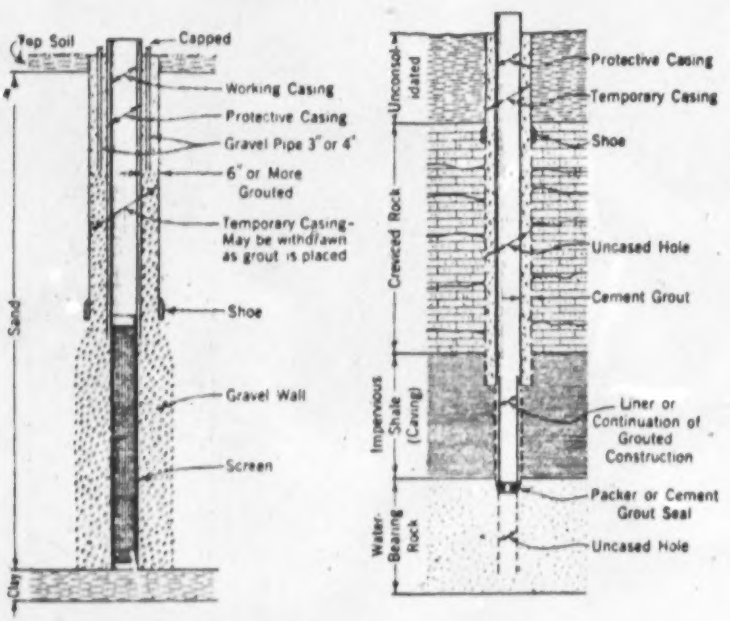


TYPICAL SHALLOW DRIVEN WELL

Deep Wells. When the top strata are too impervious or do not contain ground water, wells must be either drilled into rock to obtain water from crevices or through the soil to deeper water bearing strata (aquifers). Although the elimination of nearby sources of pollution is important, it should be remembered that polluting material may pass through fissured rock for great distances without the improvement in the quality of water which would result from filtration through the subsoil.

Drilled wells are four to 12 inches in diameter, although in some instances they may be larger. Metal casings can provide effective protection against the entrance of surface water and polluted ground water, if the casing is sealed to prevent the entrance of all sources of pollution. When the water bearing material is sand or gravel, a well screen is usually attached to the bottom of the casing. Since water can only be lifted a maximum of about 20 feet by suction, the pump must be located below the ground surface near, or below, the water level in the well.

Gravel packed wells are often used when the water bearing stratum contains fine sand. Such a well is similar to a standard well except that for several inches around the well screen the sand has been removed and replaced with gravel. This type of construction increases the area of contact with the water bearing stratum. Resistance to the flow of water into the well area is decreased and the capacity is increased. The gravel outside the screen also helps to prevent sand from being drawn into the well during pumping. The overall operating results of a gravel packed well have been very satisfactory and some authorities advocate gravel packing as standard practice when tapping any water bearing stratum of unconsolidated material. The actual placing of the gravel may be done in a number of ways but requires skill and experience on the part of the well driller.



DEEP WELLS

"WELLS"*

Some of the terms which will be used in the following discussion and illustrations should be explained:

Pervious means that water can pass through. Impervious means it will not.

Static level is the height to which the water will rise in the well when the pump is not operating.

Pumping level is the level at which the water stands when the pump is operating.

Drawdown is the distance or difference between the static level and the pumping level. When the drawdown for any particular capacity well and rated pump is determined, the pumping level is determined for that capacity. The pump bowls are located below the pumping level so that they will always be underwater. When the drawdown is fixed or remains steady, the well is then furnishing the same amount of water that is being pumped.

Cone of depression. As the water in the well is drawn down, the water near the well drains or flows into it. The water will drain further back from the top of the water table into the well as the drawdown increases. In the drawing (Figure 2) the line outlining the cone of depression actually shows the slope along which water from the surrounding water-bearing sands is flowing or draining.

Radius of influence is the distance from the well to the edge of the cone of depression. It is the radius of the circle around the well from which water is flowing into the well.

Annular space is the space between the casing and the wall of the hole.

Specific yield, the geologists' method for determining the capacity of a given well and the production of a given water-bearing formation, is expressed as gallons per minute per foot of drawdown.

After the water falls to earth, varying amounts percolate downward and reach the zone of saturation. Usually there will be an impervious layer or stratum upon which the pervious (porous) material rests. This area holds water and it may be moving slowly. The top of the water in this holding layer or stratum is known as the ground water table.

If this ground water table reaches the surface, such as on a hillside, a spring occurs as shown in Figure 1. Wells may be obtained by drilling into the water-bearing material below the top of the

*Source: Water Works Operators Manual, Alabama Department of Public Health, Bureau of Environmental Health, Third Edition, 1972, Chapter IX, pp. 2-16.

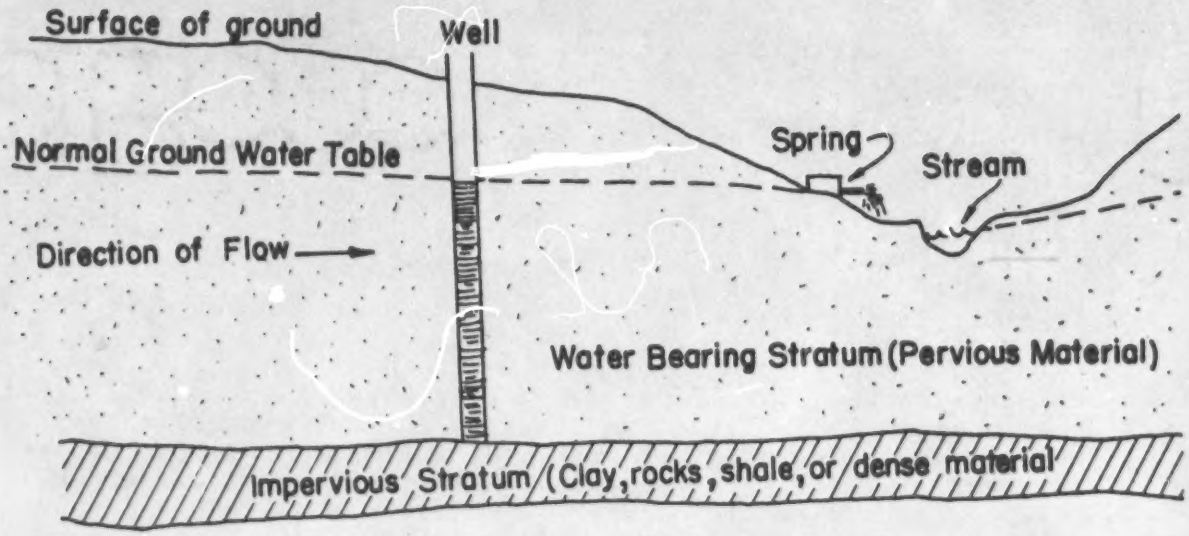


Figure 1. Simplified sketch relating to ground water.

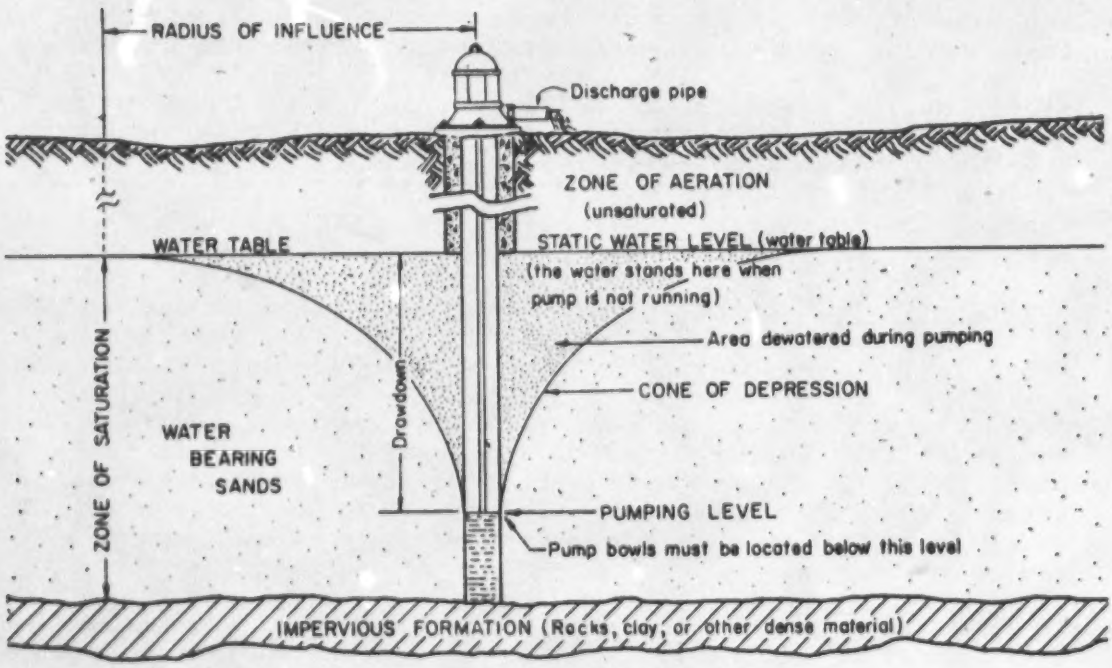


Figure 2. Schematic drawing of a drilled well illustrating terms commonly used.

water table. A number of conditions affect the amount of water which will be obtained. The thickness and continuity of the stratum, the size of the particles of material, type material, the recent rainfall and other factors all determine how much water can be obtained from such wells and springs. Note that in the drawings, the water in the well will rise no higher in the well than the water table level. Figure 2 shows a well in this formation being pumped. From this drawing, it can be realized that should a long dry season occur or a larger pump be installed, the pumping level would be lowered and the pump bowls would have to be lowered.

Rains fall on the outcropped sandy area and percolate down through it. Water fills the porous area. Since this area is full and the water is entering at a much higher elevation, it is under pressure at the points where the well is drilled. Where there is enough pressure, a flowing well will occur. This is called a flowing artesian well. Well No. 1 (Figure 3) illustrates an artesian well; however, at its location there is not enough pressure to cause it to overflow.

If enough wells are drilled and allowed to flow unrestricted, the water-bearing zone will be partially depleted or the pressure greatly lowered. When this happens the well ceases to flow. This is similar to putting too many water services on one main. For this reason, all flowing wells should be capped or plugged when not in use. Periods of drought can cause the yield of these wells to diminish also.

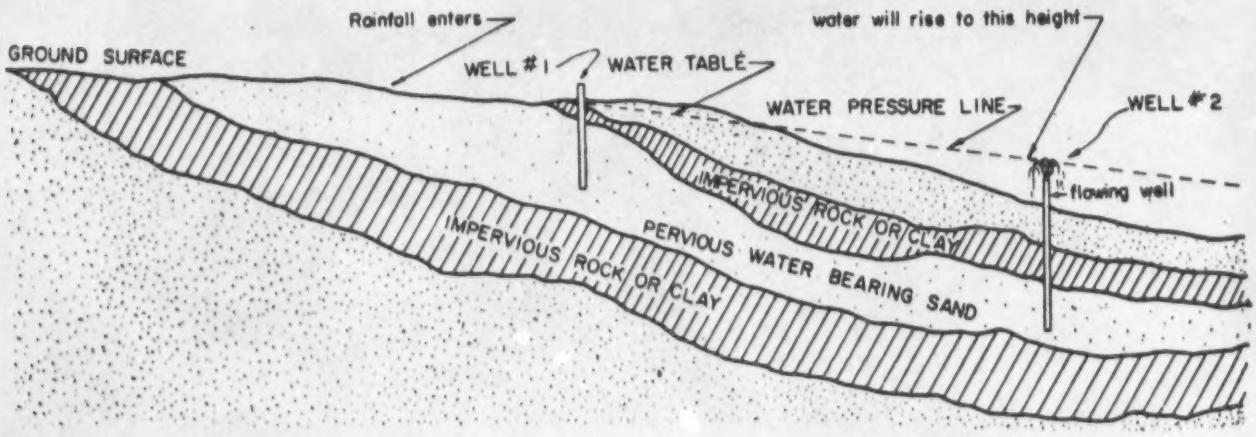


Figure 3. Conditions necessary for artesian system. Rain falling on the outcrop area moves downward into the water-bearing sand and is confined under pressure. Water levels in the wells rise toward the surface; and where the land surface is low enough, as in Well #2, the well will flow. Well #1 is a non-flowing artesian well.

In many areas of the state, water is obtained from limestone formations. To obtain a well in these areas, the well must be drilled in a location so that a cavity, crevice, or solution channel is encountered. Solution channels are caused by the water eroding and dissolving away the limestone. Whereas artesian water flows or seeps through sand, the water in a solution channel is more or less free flowing. These channels may be directly connected to the surface and the surface opening may be nearby or many miles distant. Many of the wells in such areas are so directly connected with the surface that they will become turbid or muddy soon after a rain. Wells in limestone areas should be kept under constant surveillance and continuous checks made on the bacteriological quality. If the wells become turbid and the bacteriological quality of the water grows worse, it may be necessary to resort to complete treatment. Surface streams or sewage may enter through the surface openings. It is, therefore, easy to see why rock wells or wells in limestone areas must be continuously chlorinated. (See Figure 4)

Care must be taken not to place wells too close together. If the cones of depression (or radii of influence) overlap, then the well will not produce as much water as when properly spaced. As a general practice, public water supply wells should not be spaced closer than 1,500 feet apart and a half mile is better.

All other things being equal, it is wise to locate wells on the opposite sides of town with the elevated storage near the middle. By doing this, the wells would not affect each other and the system would be greatly strengthened.

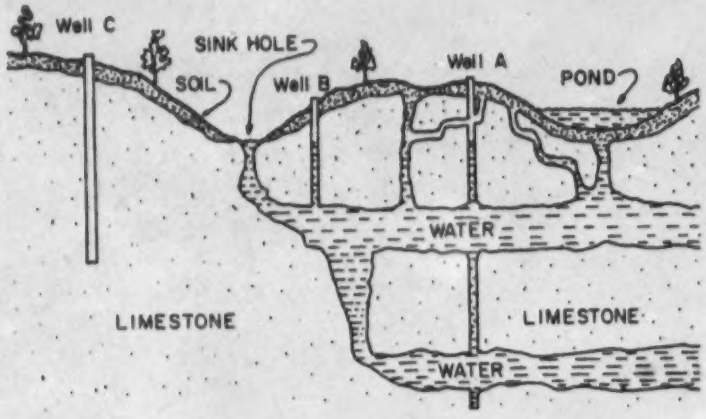


Figure 4. Three hypothetical wells, tapping ground water in solution channels in limestone: Well A, successful and yields water throughout the seasons; Well B, only partly successful because it would be dry during prolonged droughts; Well C, unsuccessful because it penetrates no solution channels. This illustrates why and how wells in limestone areas are many times unsatisfactory and dangerous. In this instance, surface water enters freely and nearby. The wells would possibly produce turbid water and contain dangerous waste material.

Figure 5 shows how the cone of depression is affected when wells are placed too close together. As shown in the illustration, the radius of influence from the two wells overlap when both wells are pumped, thus lowering the normal water level in both wells. The end results is that the efficiency of both wells is reduced.

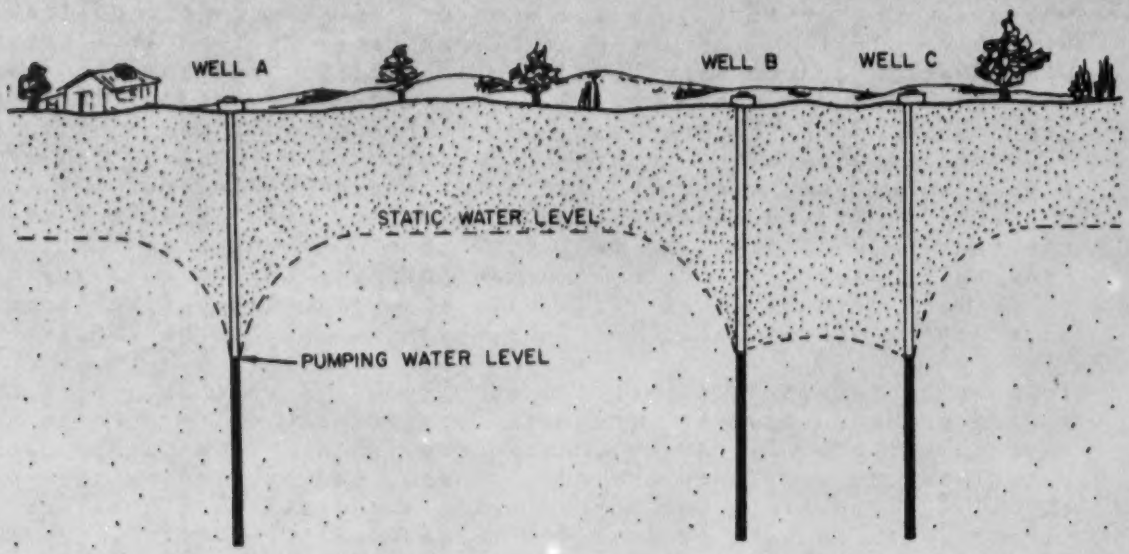


Figure 5. Three pumping wells. Well A is properly spaced in relation to Wells B and C. The cones of depression around Wells B and C overlap and cause a decrease in yield and an increase in pumping cost in each well.

Wells

Many towns and cities have suffered financial losses and inconvenience because they selected a driller on the basis of a low bid and had no specifications. Buying the lowest priced well may be even more risky than buying the cheapest article when there are several grades and price ranges to select from. A well is in the ground and cannot be examined closely. The integrity, experience, equipment, and financial responsibility of the driller should be considered. The city or water board has a perfect right to expect and receive a properly constructed well which will furnish the stipulated amount of water and give long and economical service. Some have suffered loss even when there have been specifications because there was no one representing the city who could see that the well was constructed in accordance with the specifications or no one present when the tests were made.

A test well or wells should be made before the final selection of the site is made and construction is begun on the permanent well. A test well permits the exact geology, as well as the quantity and quality of the water, to be determined. The officials are many

times reluctant to pay for drilling and testing test wells even though they are buying very valuable information. Test wells permit different areas to be investigated. Many times abundant water has been found where none was thought to exist. On more than one occasion, the community thus was able to obtain a ground water source rather than resorting to a higher cost surface supply. One site will yield water with a high iron or other mineral content, whereas another site will yield water containing no undesirable minerals. In many instances it has appeared that an iron removal plant would be necessary, but by prolonged pumping the iron content was reduced to an acceptable limit. In other cases the iron content could not be reduced and the treatment plant was constructed. Thus, testing permits the proper decision to be made before relatively large sums are committed or even expended wastefully. No money is wasted in constructing test wells, even or especially if the test hole is dry. No well site should be purchased until the test well has proven it to be satisfactory. An option may prove to be much better. Test wells will also reveal the likelihood and adequacy of ground water for future expansions to the supply.

To most untrained or inexperienced persons, a well is just a hole in the ground. However, there is considerable difference in the ways in which wells can be constructed. Many are a highly complicated structure. There are dug, driven, and drilled wells. Practically all public water supply wells are drilled. There are several methods used by drillers to make wells. Various types of bits are used to pierce the different formations encountered. The drill cuts off bits of material. This material may be bailed out or, when a rotary-type drill is used, the material is forced or floated out. This is accomplished by pumping drilling mud down the hollow drill stem. The mud is a mixture of a special clay and water and it circulates during the drilling operation. In addition to floating out the cut material, the heavy mud mixture which fills the entire hole prevents caving and cools the drill bit.

After the drilling operation is completed, the casing is set. Steel pipe is the material usually used and the sections may be threaded or welded. No secondhand or reclaimed pipe shall be used in the permanent construction of any well intended for supplying water for human consumption. The casing is to prevent caving, packing, and surface contamination. The amount of casing required is determined when the test hole is made. The casing may be placed while drilling if loose material is encountered. Ordinarily, the casing is placed when the hole has been drilled to the top of the water-bearing stratum. The casing should extend from the water-bearing stratum to at least 18 inches above the ground surface. When water is derived from rock formations, the casing should be set at least 5 feet into the rock. The hole should be at least 4 inches larger in diameter than the casing to allow for cement grout. (This space between the casing and the wall of the hole is known as the annular space.)

The next step is of the utmost importance since it involves the protection of the water to be pumped from the well against bacteriological and chemcial contamination from surface as well as unde-

sirable subsurface water. Independent of any other conditions, although location, drainage, and proximity of contaminants are important, this can only be effectively accomplished by sealing the annular space. Since this is so important, it is a requirement. No trade or deal for drilling a well should be closed until there is assurance that the driller can pressure grout the well.

The well is cemented to prevent surface waters from contaminating the well by flowing or seeping down through the annular space. The cement also protects the steel casing from contact with corrosive soils and waters which would cause it to rust out. There may also be seams or strata bearing undesirable water near the surface or at lower depths which would be sealed out. It must be remembered that in drilling a well, several seams or strata may be tapped and some of these may be very undesirable. A stratum near the surface could be highly contaminated and another at a lower elevation could contain high quantities of iron, sulfur, or other materials. Either or both of these seeping or flowing down into the well through the annular space could easily render the main cavities or strata unusable. Merely driving the casing into rock does not seal out the undesirable waters. Figure 6 illustrates the proper and improper types of rock wells.

The well is cemented by filling the annular space with high early-strength (quick-setting) neat cement. Neat cement is Portland cement without sand or gravel. The *cement is pumped* or forced into the annular space *at the bottom* of the casing until it rises to ground level. In this manner the cement will fill all spaces. The annular space is usually very small (2 to 3 inches); therefore, the cement cannot be poured around it and properly fill the hole.

The next point of consideration is screens. Many rock wells are not equipped with screens. Where water is obtained from water-bearing sands, some type screen must be provided. The selection and construction of this section of the well is most important. The life of the well depends to a large degree on the proper screen. The screen is just what the name implies--a device to hold back sand or any other foreign matter and let water through to the pump. The screen is placed in the well where it is not available for inspection and repair, and the life and performance of the well is dependent upon it. Therefore, serious consideration should be given to its selection.

Perhaps the two most important items for consideration in selecting the screen are the size of sand encountered and the chemical characteristics of the water. The screen openings must be small enough to hold back the larger sand grains or gravel and at the same time be as large as possible so that resistance to the flow of water is reduced. The screen openings are determined after the particular sand size is determined. If the screen is improperly sized or ruptures and permits sand to pass, the pump, valves, and meters in the distribution system will be damaged and last only a short time. Meters will become plugged and complaints relative to sand in the water will result.

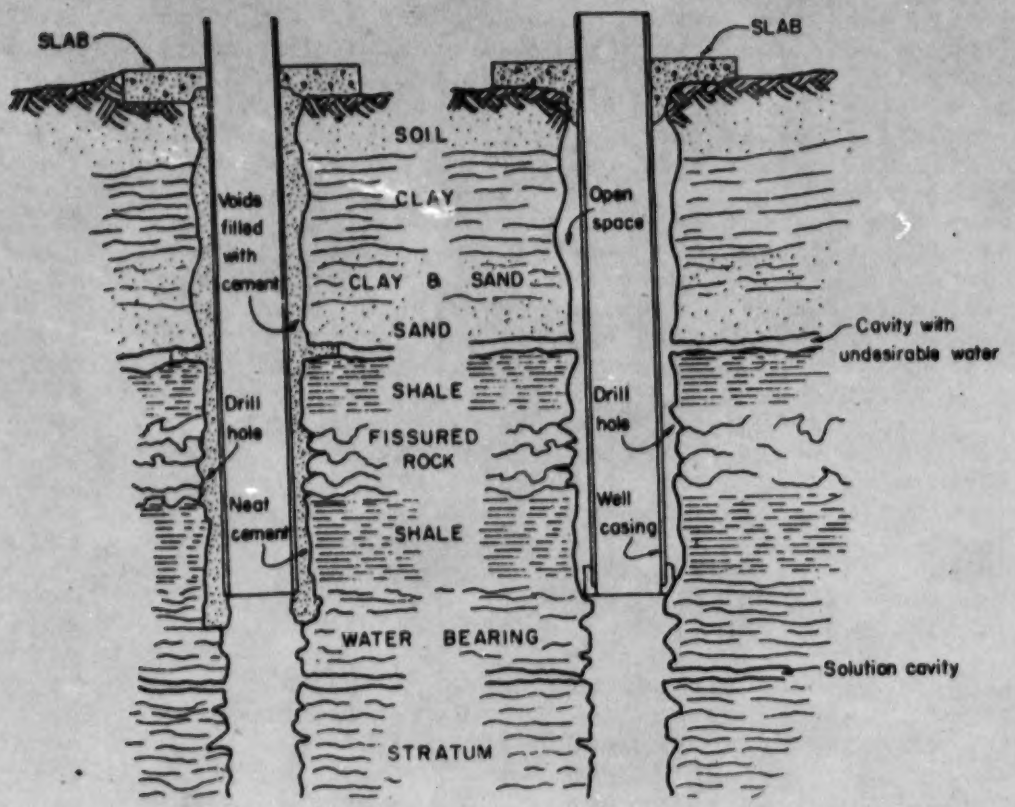


Figure 6. Drawing showing cemented and noncemented wells in rock. Note the uncemented space about the well casing on the right when casing is set in open hole. Surface water and water from undesirable strata easily flows down and into well, contaminating the water supply.

Note: In the cemented well the entire casing is surrounded by wall of neat cement, pumped into place beginning at bottom of casing and filling the annular space between casing and drill hole including all fissures and cavities.

Many of the waters encountered are corrosive for one reason or another. Screens installed in such wells must, of course, be of material that will resist the corrosive action of the water. Ordinary steel or other non-corrosion resistant material will last only a relatively short time. Certain stainless steel alloys are probably the best reasonably priced materials for use. Monel metal, a high nickel-copper alloy, is probably the best material used to make screens to be installed in acid waters. Many various materials and methods of constructing screens are available.

An item which might also be properly classed as part of the screen is the "gravel wall" built in many wells. Wells may be of the "straight" or "gravel wall" type. Gravel wall, sometimes referred

to as gravel filter, wells are constructed by drilling until the water-bearing sand is encountered. At this elevation, where the screen will be sent, an under-reamer is used. This type drilling tool has vanes or blades which open or spread. By expanding the under-reamer at the particular depth needed, the hole can be enlarged. For example, the drill hole may be 12 to 24 inches with the under-reamed portion 20 to 48 inches. The liner, made up of sections of screen and blank pipe, is set in the finished hole below the upper well casing. The blank pipe above the screen laps upward into the casing for considerable distance. Carefully selected gravel, based on the size of the sand in the water-bearing strata, is chlorinated and pumped into the space around the screen in the under-reamed portion. The gravel acts to prevent particles of sand reaching the screen. Note in the illustration (Figure 7) that the gravel extends upward into the space overlapped by the blank pipe.

A well constructed without under-reaming and filling the resulting space with gravel is called a straight well (Figure 8). They, of course, cost less money. After the proper sized screen is set in the hole, the well is developed. The size screen openings needed is determined by an analysis of the sand found in the water-bearing formation. It is pumped at as high rates as possible in such a manner that the fine particles or grains are removed or pumped out. This leaves the large sand grains and gravel which form an area around the screen. The water must pass through the voids. In most instances, the voids would be irregular and probably smaller than voids created by selected and sized gravel as found in a gravel wall well. Plugging is much more likely to occur. A properly constructed and properly developed straight well could be serviceable and give long service. It is very unlikely that it will be as dependable and serviceable as a gravel wall well.

Listed here are some of the advantages of the gravel wall type well: (1) Larger screen openings, not easily encrusted or clogged, provide for longer useful well life. (2) Although larger screen openings are used, movement of sand is reduced by gravel-wall because of a decreased velocity through this filter bed. (3) The pumping cost is less due to freely flowing water through the gravel bed which results in less drawdown. (4) Production is larger due to larger diameter hole in water-bearing sands.

Cemented, gravel wall wells are the recommended type. This recommendation is made freely since there are several drillers in the state who make this type well. Remember, *the annular space must be sealed for protection and cementing is the only practical way to do this.*

Well Development and Testing

When the well has been completed, it should be developed. Development is a procedure to get rid of the fines, very fine sand and other material, and to so arrange the larger grains of sand that the highest capacity possible can be obtained. There are several

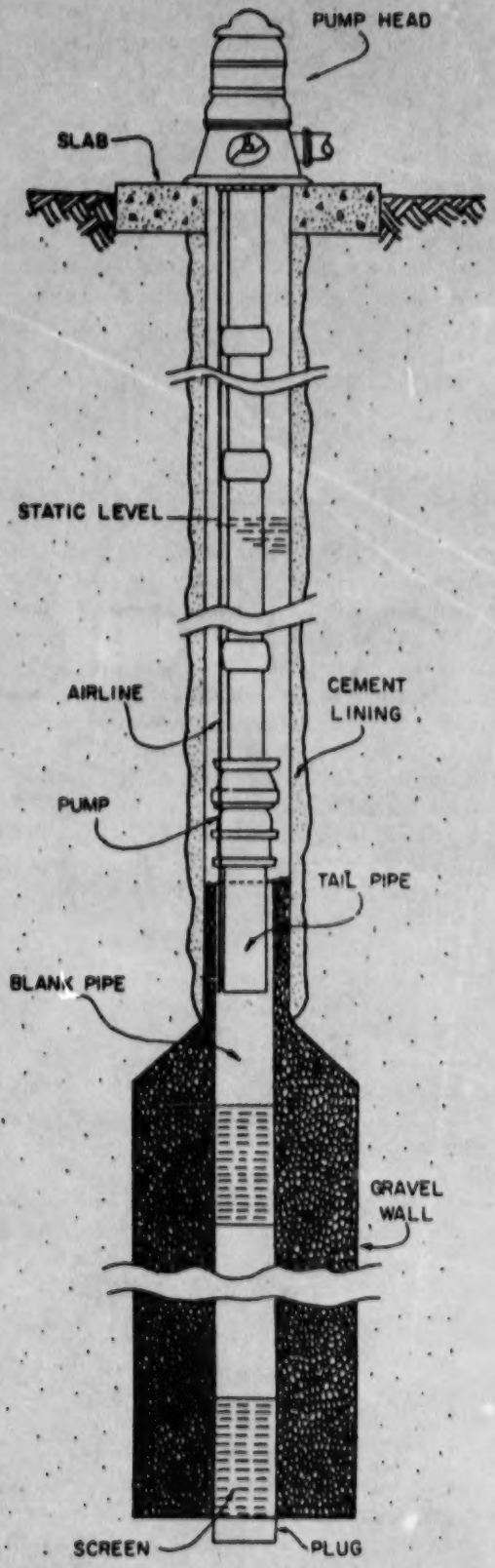


Figure 7. Cement-grouted gravel wall well.

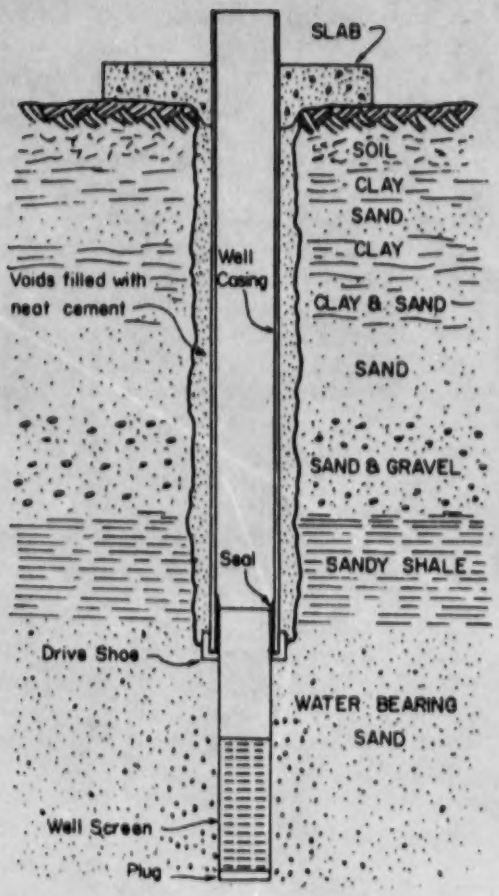


Figure 8. Straight well. Fine sand removed by pumping. Screen prevents larger grains entering.

ways in which the well can be developed. Some of the methods used are surging, swabbing, backwashing, or using compressed air. These procedures force water in and out through the screen, removing drilling mud, fine sand, and other foreign matter. A regular pump or airlift may be used during this development pumping. *The pump which is to be installed permanently in the well should never be used for this purpose.*

The specifications should call for a test to be made on the well after it has been completed. The output of the well should be measured. Weirs, orifices, or other measuring devices are used to determine the capacity and drawdown. Drawdown has been explained previously. If a well will yield 50 gpm with a 25-foot drawdown, it will possibly yield 100 gpm with a 50-foot drawdown if a pump of sufficient size is installed to effect a 50-foot drawdown. Usually, during the test, a pump much larger than the anticipated size of the permanent pump is used, and it is powered by a variable drive engine so that tests of varying capacities can be made. Tests vary from 8 hours to 48 hours of continuous pumping. The test should be of such duration that stabilization of the water level is established and the safe yield is determined. Also, it is very important to record the well recovery rate after the test pump is shut off. It goes without saying that the longer the test is run, the more reliable the data obtained will be.

Rock wells (wells obtaining water from a limestone or rock aquifer not equipped with screens) on occasion are more difficult to clear when developing. This is attributable to some extent on the specific gravity of various sedimentary particles (sand, micaceous matter, etc.) in the solution channel and the velocity of the water in the aquifer under sustained pumping conditions. As a result of these conditions, it often becomes necessary to wire a timer into the pump circuit so that the pump operates at a given capacity for a period of time. This allows the heavier particles in the aquifer to settle. When the pump is again started, the velocity of the moving water may or may not pick up these particles again. If this operation is continued over hours and perhaps several days, the well may be developed to produce at a given capacity which is turbidity free. Also, small particles may be sheared off of the stone in the aquifer during each operation. These particles that are susceptible to this condition may also be removed a little at a time until all has been cleared. Generally speaking, it takes many hours and sometimes weeks of pumping to clear the discharge from a rock well.

At this point, the problem of "over pumping" a well will be briefly discussed. On several occasions in Alabama, wells have been constructed and developed to produce a given quantity of water and have been pumped at a greater capacity due to the installation of larger or oversized pumps, improper valving when pumping to waste and reduced pumping head as a result of rearrangement of some piping and changing of water level controls, etc. For this reason, it is usually good practice to develop a well at a larger capacity (25 to 50 per cent greater) than that of the proposed pump, providing, of course, a given well will yield a sufficient quantity.

Test pumping and developing a well in this manner will also provide valuable information relative to ground water availability in a given area. One should always be wary when operating a well pump under any conditions other than those for which the pump is designed. As a result of "over pumping", "channeling" may develop through the gravel pack in a gravel wall well which may result in small particles of sand passing through the gravel pack and screen. (Such a condition may also be the result of screen failure.) Similarly, the drawdown in a rock well may be excessive to the point that the drawdown level may fall below the aquifer roof. If sustained pumping at this rate continues for several hours, the aquifer roof may cave causing sink holes in the area. It may dry out and crack to some degree; and when the well again recovers, the roof may partially collapse as a result of the returning moisture. Also, when the pumping rate is increased (over pumping), the water velocity through the aquifer increases and may increase to such an extent that a "mud slide" or movement of the heavier particles previously mentioned may result. These conditions, of course, if left unheeded will likely result in failure or severe damage to the well construction and necessitate repair.

After a well has been completed or if any repair or maintenance work is performed, chlorine should be used to thoroughly disinfect it. A very strong chlorine dose, using hypochlorite (70% available chlorine), is needed in a new well (approximately 50 ppm). To disinfect a well already in use, but from which unsatisfactory samples have been obtained, 5 to 10 pounds of hypochlorite are used.

Air Line

Some method for measuring the water level at future times should be provided during the construction of the well. Probably the most commonly used device is an air line which is a tube, usually copper, installed and extending from the surface to a point just above the strainer or tail pipe with a pressure gauge and Schrader valve at the upper end. All joints must be airtight. This tube *should be no less than 3/8-inch.* This tube should be installed at the time the permanent pump installation is made. In order for the tube to be of use, its length must be known. If the gauge is calibrated in feet of water rather than pounds per square inch, no conversion will be necessary in determining the water level. Many times the air line will break, corrode, or otherwise develop an air leak. When it appears that this has happened, there should be a way to insert a tape or other measuring device. Therefore, a second line should be installed so that the water level may be checked with a tape.

The water level is determined by attaching a hand air pressure pump of some type (such as a tire or bicycle pump) to the valve. The gauge should be set at zero before air is pumped into the tube. When the movement of the needle on the gauge reaches the point where it remains stationary, the gauge reading in feet will show the distance from the water level to the end of the tube. The

needle remains stationary after all the water standing in the tube has been forced out. The reading is equal to the feet or pressure necessary to support a column of water of height equal to that forced from the air line and is the same as the length of the part of the air line underwater. Thus, by simple arithmetic, the elevation of the water in the well can be determined. By using the following formulas and referring to Figure 9, the static level and the pumping level can be found.

L - WS = SL or static level
L - WP = PL or pumping level

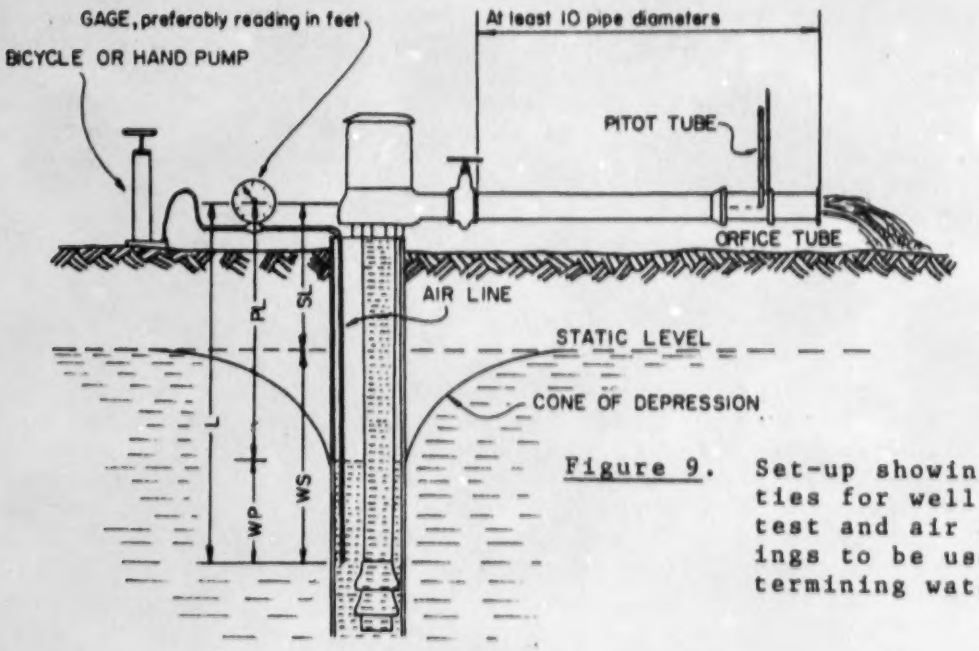


Figure 9. Set-up showing facilities for well production test and air line readings to be used in determining water levels.

If the gauge reads in pounds per square inch, then the conversion factor 2.31 must be used to determine the depth of the water in feet (2.31 x p.s.i. = feet). A good operator will maintain a permanent record of the water levels and recovery times in his well. This can be valuable information to him. If the records indicate that the drawdown is increasing, or the water rises to the original static level more slowly than formerly, the trouble may be a clogged screen or blockage around the screen. If the record indicates that the static level has been permanently lowered, the trouble is likely to be from increased pumping of water from the same water-bearing strata. Of course, a severe drought could also be responsible.

Pumping Test

The importance of testing the well has been mentioned. In addition to determining the well yield at the time of construction, all

wells should be test pumped for capacity, comparative drawdown, and recovery at least once a year. The quantity of water pumped can be measured with an orifice tube if the pump can be operated at a constant rate, metered, measured in a vessel such as a 55-gallon drum, or estimated as outlined below. As has been mentioned, provision is needed to measure the drawdown and recovery. When the pumping test first begins, the water level lowers rapidly and, therefore, water levels must be measured at shorter intervals than later when the level ceases to drop so fast. The pumping rate should be checked every few minutes as it tends to decrease as the water level drops. After the pumps have been stopped, measurements of the rise of the water level should be made quite frequently during the early part of the recovery period. The data collected during recovery many times gives a better picture of the characteristics of the water-producing area than the data obtained while pumping.

The two general types of tests are known as the step drawdown test and the constant rate test. The former is used to test well or pump capacity or pump efficiency. The constant rate is used in determining the characteristics of an aquifer. Observation wells are usually used to fully determine the aquifer characteristics.

Estimation of Flows

There are many times when an operator wishes to make a quick estimate of a flow from a pipe. Several magazines have carried a little article showing an easy way this can be done. A surprisingly close approximation of flow can be made by means of a few simple measurements. The drawing, Figure 10, shows the two measurements which must be made and the only equipment needed is a straight edge and an ordinary rule.

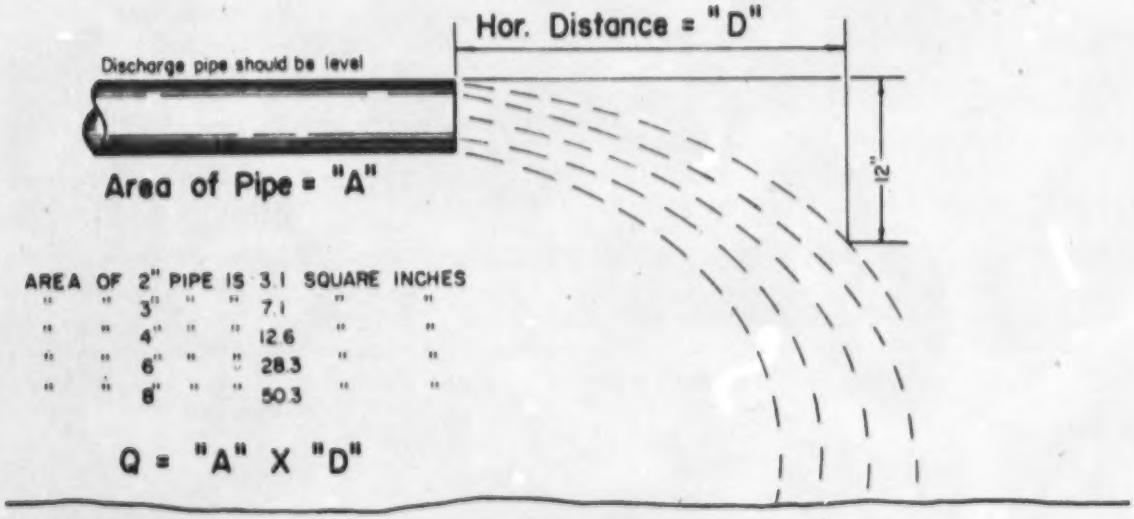


Figure 10. Method for estimating the flow from pipe.

The pipe must be flowing full in order to make this estimate. First measure the distance ("D") horizontally from the end of the discharge pipe to a point which is exactly one foot above the falling stream of water, as indicated in the drawing. The distance ("D") in inches multiplied by the area of the pipe in square inches will give the quantity in gallons per minute, which should be within 5 per cent of the correct amount.

The formula for calculating the estimate of flow is:

Q(quantity in gpm) = A(area in sq. in.) x "D"
(in inches)

For example, in making an estimate of flow from a pump, suppose "D" is 24 inches and the discharge pipe is 6 inches in diameter. The area of a 6-inch pipe is 28.3 square inches.

$(A = \frac{\pi}{4} D^2$ *or* $0.785\ D^2 = 0.785(6)^2 = 28.3)$

28.3 x 24 = 680 gpm.

Therefore, a safe estimate would be 700 gpm.

Pumps

The subject of pumps will be dwelt on very briefly. Most pumps being installed in public water supply wells at the present time are vertical turbine and a few submersible types. Submersible types seem to be becoming more common in smaller wells as replacements and especially where the well is not plumb.

The vertical turbine should be mounted on a good base or foundation, and it should be installed in such a manner that there is no vibration. A popular method of testing for vibration is to balance a coin on its edge on top of the motor. A small amount of vibrations makes this impossible. Too few well pumps are being provided with gasoline, diesel, or natural gas engines for standby power so that water will be available when it may be needed most; that is, when a storm or some catastrophe has knocked out electric power. It is an excellent idea to provide this auxiliary power where possible.

Where the water is pumped directly to the system, the pump discharge line should be equipped with an air relief valve, check valve, pump-to-waste line, pressure gauge, and gate valve. A meter on the pump discharge line is necessary if the water works is to be operated on a business-like basis as it provides the information to make a comparison of "water pumped" to "water sold". It is helpful in finding leaks and determining cost of production. The air relief valve should be installed to eliminate the air which is in the pump column at the time the pump starts. If this air is pumped to the system and is unable to escape, the water may have a "milky" appearance when drawn from the spigot. Upon setting a few minutes, the air will dissipate from the water; however,

air in the water will cause many complaints. Figure 11 shows a general piping layout for a deep well pump which includes the pump-to-waste line.

The pump-to-waste line provides a means whereby the yield can be determined exactly or may be estimated. Also this pump-to-waste line makes it easy to: (1) check to see if the pump is producing sand from the well; (2) flush the main leading to the distribution system (by backflow from the distribution tank); (3) pump to waste super-chlorinated water from the well after disinfection; (4) pump water to waste to help clear the well should complaints regarding turbidity arise; and (5) if for some reason a well has been out of use for a period of time, it can readily be pumped to waste before it is used again.

In most cases, the pump operation should be controlled by automatic controls from either the water level in the elevated tank or from pressure actuated devices. By using automatic controls, the storage facilities can be kept more nearly full at all times. The advantage of this is obvious since fires or other disasters usually occur without advance warning. Even where the automatic controls are used, the wells and pumps should be visited twice daily and probably more often.

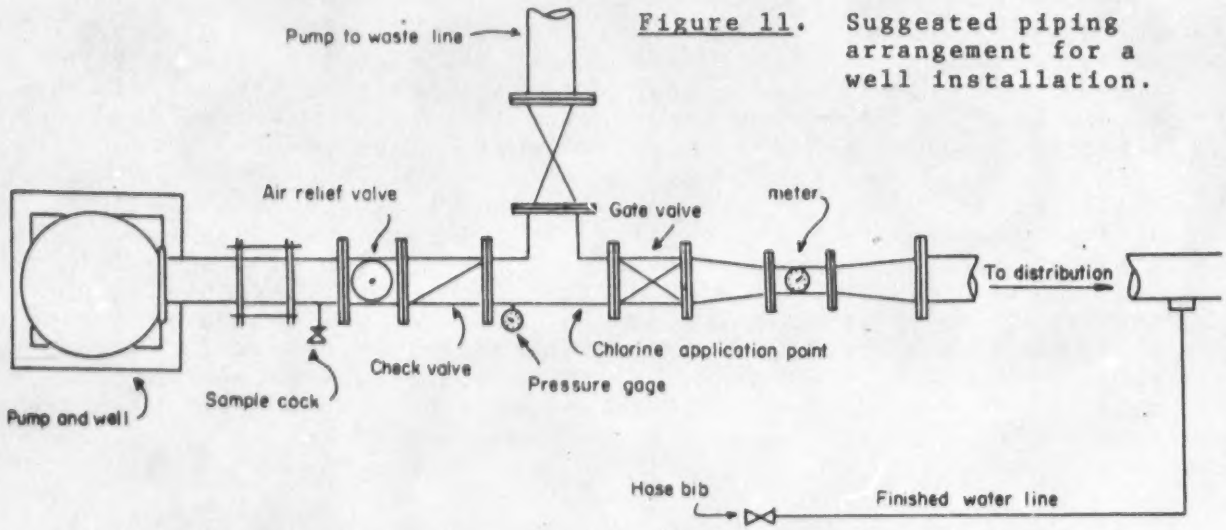


Figure 11. Suggested piping arrangement for a well installation.

Pump Maintenance

The modern day pumps require only a relatively small amount of maintenance; however, some items such as oiling and greasing are required regularly. This is particularly true relative to the pump bearing oiler, since the rate changes with temperature. It should be set to drop 4 to 12 drops per minute each season of the year and checked on unusually warm or cold days. Too much oil should not be applied. The oil is not burned or used but passes the bearings and accumulates on top of the water in the well.

Thus, it is wasteful and a large quantity on top of the water could more easily pull down into the pump suction or tail pipe and be pumped to the system. The oil reservoir for oil to lubricate the shaft bearings should be cleaned at frequent intervals to prevent water and sediment accumulations. Many pumps are provided with a reservoir in the pump head for oiling the top bearing. This oil should always be maintained at the proper indicated level and changed in accordance with the pump manufacturer's recommendations. In all cases, maintenance to pumping equipment should be accomplished in strict accordance with the manufacturer's recommendations.

All well and spring pumping facilities should be visited often and at least twice daily. During the visit, one should always listen for unusual sounds emanating from the well pump or pumps. An experienced operator can detect many developing problems by mechanical sounds. One should frequently check also for pump vibration. This may be done by placing one hand on the top of the pump. In this manner, unusual vibrations may also be detected which may indicate bearing failure or similar situations. During visits when the pump or pumps are not running, one should listen for flowing water. A leaking check valve can easily be detected in this manner. The check valve should be repaired immediately since this is wasteful and poor operation.

Requirements

The first item of consideration after it has been decided to make or use a well or wells is to properly select the location. Three major items of consideration enter into locating the site. First, the well must be located in an area where underground water is available. Secondly, the well must be located so that a bacteriologically as well as chemically safe water can be produced. Third, it should be located, depending upon the first two items, so that it will serve the community best and most economically.

The contamination of wells and springs, except those in areas where the water is from limestone foundations, usually comes directly from the surface. Water, after it has traveled long distances underground, has spent days, weeks, and even years flowing through sands and other material. The filtering action in addition to the time element should eliminate harmful bacteria. Thus, if surface washings are kept out, ground water should be fairly safe.

The first precaution to take in selecting the well site is to apply the following rules in making the location. Of course, a spring is where it's found and man can do little to change its location. However, its location may determine whether or not it is usable. The following fundamental principles should be observed.

The well or spring should be located:

(1) At the highest point on the premises consistent with the general layout and surroundings, but in all cases it shall be protected against surface wash and flooding.

(2) As far removed and in a direction opposite to the underground flow from any known or probable source of pollution as the general layout of the premises and the surroundings will permit.

(3) So that sewers, septic tanks or disposal fields shall be, now and in the future, at least 100 feet from the site; and all sewers which are constructed nearby shall be of cast iron pipe with tight joints. Therefore, all well lots should be no less than 200 feet square so that no sewer, septic tank or other undesirable facility can be located closer than 100 feet to the well.

(4) So that the proposed well shall be as far removed as possible from abandoned wells or areas which may allow seepage. Where abandoned wells are nearby, they shall be filled with neat cement grout, concrete, or clean puddled clay with a concrete cap. (Where the wells penetrate water-bearing sands of good water quality, that aquifer should be filled with clean sand, sealed, and the remainder of the well properly filled.)

Determination of the best location for the well from an engineering standpoint may require considerable study. The best location will also depend upon the size and the geographical layout of the community, the direction in which growth is taking place, the location of the areas designated for industrial development, and the location of other wells and elevated tanks. A simple example of considerations in locating a well follows:

Assume that a community is stretched out along a highway for about a mile and at one end of town there are some relatively high hills. It would probably be more economically feasible to locate a storage reservoir on a hill rather than to construct an elevated tank. In such a case, the desirable location of the well would be at the opposite end of town from the reservoir, if water is available in that area. By so locating the well and tank, water for fire fighting or at times of high demand could be secured from both the well and tank. With a minimum number of valves, during times of maintenance work on the well, tank or distribution system, a considerable portion of the town could continue to get water. Generally speaking, where there is more than one well and possibly only one tank, it would appear unwise to group the wells around the tank. Of course, it is very unwise to place wells so close together that one will affect the yield of the other. There are cases where more than one is drilled on the small lot on which the elevated tank is located. Wells may be logically placed close together only if they are not taking water from the same stratum.